PROCEEDINGS

OF THE

AMERICAN SOCIETY OF MICROSCOPISTS.

ELEVENTH ANNUAL MEETING.

ANNUAL ADDRESS OF THE PRESIDENT:

THE NATURE OF PROTOZOA AND LESSONS OF THESE SIMPLEST ANIMALS.

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Fellows of the American Society of Microscopists, ladies and gentlemen: —

In accordance with well-established precedent and by your kindness, it is my privilege to address you this evening hour of the first day of the annual meeting. In making choice of a theme I have been guided largely by the safe examples of my learned and distinguished predecessors who have addressed you on similar occasions, and who have preferred to discuss topics pertaining to their special fields of research rather than to present a general review of the progress towards the perfection of the microscope and its accessories, or to the mass of varied research with the instrument. The President last year, at Pittsburg, in beginning his address, said: "Microscopy is more nearly cosmopolitan in its character than any other science. If I did not believe

this I should not have consented to occupy this honorable position which I now hold by your suffrages. I suppose I am indebted to this expression of your confidence on account of the use which I have made of the microscope as an essential factor in a single line of research." Likewise I am pleased to think that I owe my present position, first and partially, to the fact that for six of the ten years of the Society's existence I have been intimately associated with its work as Secretary, and second, but may I hope chiefly, since in one line of research with the microscope I have succeeded in bringing to light some forms of minute beings, invisible, indeed, to the unaided eye of man; some of them peculiar and hitherto unknown, while others had not been previously announced as occurring in the remarkably varied and interesting microscopic fauna of our native fresh waters. So it seems to me entirely appropriate that on this occasion I should not go outside the line of research to which the greater number of my contributions to the Proceedings have pertained; moreover it is the branch in which you know me best as a naturalist and concerning which I feel some confidence to speak in your presence. Hence, I shall ask your attention for this hour to a general discussion of the "Nature of Protozoa and Lessons of these Simplest Animals," followed by an account of what has been done in America to elucidate the group. But before proceeding with this subject permit me to extend somewhat these preliminary remarks.

The American Society of Microscopists, like kindred societies everywhere, is composed of those who use the microscope in many and widely different branches and activities; the most useful instrument of investigation yet discovered by the patience and genius of men is the common bond of union; it unites those having little else in common save an enthusiastic love of truth, and, naturally, it gives name to these organizations. All who depend upon the powerful aid of the microscope are intensely interested in its improvement

and its final perfection. Moreover, the improvements in the methods of its use and the complicated and delicate operations necessary to its fullest revelations are of scarcely less importance. The microscope and all that pertains to it, its manipulations and the many refinements of methods of research into the constitution of the minute, are, therefore, plainly the first subjects to be considered as the especial province of this Society. These should, unquestionably, receive first place in its deliberations.

This matter was forcibly put four years ago, by Judge Jacob D. Cox in opening the Rochester meeting of the Society, and quite recently Rev. W. H. Dallinger, President of the Royal Microscopical Society, has expressed similar views. The opinions of these representative men can not be lightly set aside nor their advice neglected. Their conclusions are the results of rich experience in affairs. The wise man it is said — and is it not also true of organizations of men, is one who profits by the experience of others; the foolish, who gains by his own experience only. Is this society in danger, or is it likely to drift into that unhappy state of forgetting "That in proportion as the optical principles of the microscope are understood, and the theory of microscopical vision is made plain, the value of the instrument over every region to which it can be applied, and in all the varied hands that use it, is increased without definable limits?" The records will show, I think, to any enquirer that the chief reason for the Society's being has been remembered thus far in its history, and the wise councilors and guides which it fortunately possesses give confidence that it will not in the future depart from its safe traditions. The society has discussed and published numerous papers on the theory and construction of the microscope, new forms, improved methods and devices; it has taken measures, equaled by no other society, to secure a standard of micrometry, it has sought to secure uniformity of tube diameter, improvement

in eye-pieces, in the Society-screw, etc. Again, besides the papers on microscopy, at every meeting there have been free exhibitions of instruments of the latest forms made at home and abroad, and annually, beginning with the Chicago meeting in 1883, there has been, in addition, a thoroughly organized practical session at which many difficult operations have been explained and demonstrated by those fully competent to teach. The Society then surely has not fallen into the grave error of neglecting microscopy for the discussion of the results of microscopical research. And may it ever be kept in mind by those who direct its energies that the improvements of the "prince of instruments of investigation" and the technics of its applications are the chief aim, work, and destiny of this still young and progressive organization.

But how justify my choice of a theme for this evening: first, by the usage of the most renowned microscopical society, the Royal Society of London, the proceedings of which are largely concerned with natural history; second, the custom of this Society which has grown up in accordance with the wishes and advantages of its members; and third, it seems to me there are good and sufficient reasons why this Society should continue to receive and publish, for the present at least, the results of microscopical investigations by its members in whatever field. "Wherefore by their fruits ye shall know them." Methods and means are judged by established results, tested by comparisons and discussions; such conclusions are verities, the flesh and blood that clothe and beautify and nourish the skeleton which in turn gives form, stability, and efficiency to the whole.

If the foregoing precedents are not worthy to be followed or if there are not the good reasons alleged for occupying your attention as a society of microscopists with such subjects as that announced, then I have through an error of judgment fallen short of the full measure of my opportunities on this occasion.

In the following discourse I have endeavored to keep before me these conditions: 1, to mention only such points as reasonably possess a general interest, reserving the more technical results of my study for presentation at the daily sessions; 2, to state and illustrate these facts clearly; and 3, to occupy a reasonable time.

There is an almost universal desire on the part of the devotees of any particular art or science to date its origin in the remote past. Are we not apt to esteem most highly that which bears the stamp of hoary antiquity? I am convinced that this is the case, and yet I cannot justly claim that advantage for my specialty. Other reasons must be alleged as a warrant for especial attention to it. Still, the beginning of our knowledge of the simplest animals was laid more than two hundred years ago. The microscope of that time was indeed a primitive instrument. Its evolution had so far progressed that it was something more than a toy. By its aid at that time was revealed, in partial vision it is true, the grand fact that there exists beneath the waters of every mantled, festering pool or limpid stream, in lake or river or in ocean depths alike, myriads of invisible, minute beings, ceaselessly, noiselessly pursuing their work unheeded. As the infinite variety of graceful forms and their strange habits were more and more clearly comprehended, and as the knowledge of a newly revealed animal world increased, the enthusiasm of these early microscopists became exuberant, and with their enthusiasm grew their devotion to nature and its Author — a consequence repeated in every student who in the right spirit learns her lessons for himself by his own explorations. Men now possessed, and were beginning to employ, constantly improving microscopical vision; it revealed a world of minute animals and plants, perfect in their way, actuated and governed by principles and impulses not unlike those controlling the macroscopic already known. In these animate atoms were seen anew, or for the first time, certain world problems,

and there sprung up fresh hope of their solutions. The origin and nature of life; what guiding intelligence adjusts the varied relations and necessities of each and every minute creature to its environment as truly and exactly as in the higher organic forms. Moreover, here and there a broad unknown domain of nature was opened for exploration by the human intellect which, at that time, as it seems to us, was in the attitude of the child toward nature, eager to know its facts and the reason for them, seeking knowledge for the sake of knowing. There is no wonder that the early investigators of microscopic life were enthusiastic; they had abundant reason for this directing sentiment; their devotion and patience laid well the foundations of the science of a great branch of animals. Leeuwenhoek, Jablot, Baker, Trembly, Ledermuller, Perty, Muller, and Ehrenberg, prepared the way for the brilliant discoveries and broad generalizations of half a century just passed by the renowned students of the simplest living beings. The present knowledge of the Protozoa does not compare unfavorably with that of any other assemblage of animals and is advancing as rapidly; this, too, when only comparatively few skilled workers can contribute to this end, and, moreover, these forms are of little or no practical use or importance. Even their once supposed intimate relation as a cause to many distressing maladies has not been confirmed by recent research, but rather disproved, except, perhaps, in the rare instances of certain blood parasites or some external parasites of aquatic animals. There is, then, sufficient love of abstract truth, sufficient enthusiasm in bringing to light new facts and endeavoring to answer grave problems of philosophy, to render possible brilliant discoveries if not a brilliant scientific epoch. To these sentiments is due our knowledge of and interest in the Protozoa.

The animal kingdom is divided into two natural groups or series, the Protozoa and the Metozoa. The former includes the unicellular forms or those generally regarded as

the equivalent of the histological cell; the latter are multicellular, their tissues composed of histogenetic elements or cells, and these are arranged in two sets, viz., the ectoderm, or outside body-wall and the endoderm, or lining of the alimentary cavity. These commence existence as a nucleated cell; their subsequent growth and complexity are the result of cell multiplication and modification mingled with the products of cell life. The Protozoa do not pass beyond the primitive stage, i. e., cell division giving rise to individuals. None are modified for the sake of others, and all perform similar functions and all the essential functions of an animal. Truly, then, we have here the simplest forms of animal existence possible, while the life of the metazoon may be regarded as the resultant of hosts of individuals comprising it, and among which division of labor is fully carried out; on the other hand in the protozoon we see manifested by each individual only the capabilities of one element. In this case then we deal with the absolute elements and not with resultants. Here the mystery of mysteries seems to be almost unveiled. The nature of life, if it is to be revealed by the study of organisms which exhibit it, should appear from the study of the naked, disassociated protoplasmic atoms in which all the essential attributes of life are manifested. The simplest of these, for they differ widely among themselves — are without nerves, yet they are sensitive; they are without organs, yet they move about freely, gather, select, and digest their food, and escape from their enemies; they reproduce their kind and maintain themselves when subjected to unfavorable conditions with as great certainty as do the complex and bulky animals. In short, their life histories, as we get to know them better, prove to be as definite, the specific characters as constant. But does the clearer understanding of these forms in their simplicity shed light on the nature and origin of life which are held by many savants not to be transcendental? It seems to me not, and that we are still

very far from the solution of these great problems. The most that has eventuated thus far is a shifting of the point of view. This has undoubtedly afforded a clearer sight, but the perfect vision is not revealed. Still, while the object sought may be illusive, and, as one who pursues the rainbow finds it ever a few steps beyond his reach, so here, the answers to the questions mentioned, which have been so eagerly sought for in the bodies of the simplest and beginning forms of life, ever elude the microscope and reagents of the inquirer. Then are we no nearer an understanding of these matters than before? Most certainly we are. The problems of human society are not nearly all solved, but there have been tremendous strides in advance since the individual has been made the object of consideration rather than communities. Although the results attained are so far short of hopes and expectations, yet, in the prosecution of these inquiries in connection with Protozoa there are fascination and interest. Further than this the infinite variety, their gracefulness of form and motions, their ubiquity and high endowments coupled with simplicity, firmly hold the attention of the student.

For the sake of clearness in the subsequent parts of this discourse let us attend for a few minutes to the organisms themselves and the terms designating the parts.*

A cursory survey will disclose the fact that there exist very great differences among these creatures comprehended in Protozoa. The reach from the lowest to the highest is immense, comparable only to a corresponding relation between highest and lowest vertebrates, hence, for illustration of terms and for convenience of comparison I have chosen a species near the middle of the series; with this we may hurriedly and easily compare others, higher and lower.

If to a beaker of clear water a few fragments of hay be

* To aid in this explanation simple figures were drawn on the blackboard.

added and let stand a few days there may be found in the infusion great numbers of a small animated speck represented by the sketch. A careful study of this object has revealed interesting facts and suggested inquiries not yet fully answered. It is somewhat egg-shaped or globular, quite soft and elastic, with two similar external appendages consisting of two long lash-like fibres. Under the lens the whole organism appears endowed with life. This is attested by its free motion, sensitiveness, and ability to appropriate and change to voluntary activity the energy of organic food. The proper tests prove that its substance is identical with that form of matter everywhere associated with life, and called protoplasm. In fact this animal is little else than this remarkably complex and wonderful substance now universally recognized as the physical basis of life.

This minute lump of matter, only about $\frac{1}{4000}$ of an inch in diameter, is naked protoplasm; true its outer boundary appears to be somewhat denser than the portion included; still, it appears that its food may be taken directly through the surface at any place; there is not a food-receiving orifice — a mouth. On examining the globule further two important bodies attract our attention. First, imbedded in the protoplasm may be seen a globule of protoplasm firmer than the surrounding mass; this is the nucleus. This element of the protozoan body, possessed also by the histogenic cell, has elicited much study and animated discussion. Almost every issue of the microscopical and morphological journals bring to notice accounts of new and many far-reaching discoveries regarding it in relation to the career of the cell to which it belongs; second, within the endoplasm may be seen a clear globule which grows until a certain size is attained when a sudden collapse occurs and it disappears to again steadily form and disappear as before. The two lashes which arise from the lower anterior part of the body are extensions of the body protoplasm, hence, possessing its properties of sensibility and

contractility. One of these flagella reaches ahead and by its repeated strokes against the water pulls the body through that medium; the other is used as a director of its course or sometimes as an anchor. These few differentiated parts are all that characterize this representative of one of the great classes of one division of the Protozoa, viz., the Flagellata, the first class of the Infusoria. By variations of these parts and their products arise those characters and differences on which are established scores of genera that are simpler and scores that are more complex.

That these germs teeming in the hay infusion are alive, no one questions. But why relegate them to the animal kingdom rather than to the vegetable? It is no longer difficult to refer any one of the complex or multicellular beings to one or the other of these two parallel series; there are no longer serious differences of opinion concerning such among the learned, but to satisfactorily divide unicellular forms, placing this one among Protozoa and that one among Protophyta is another matter,—one which the present state of knowledge does not enable men to agree upon. The distinguished biologist Ernst Hæckel has proposed to remove the difficulty by establishing a third kingdom, Protista. To this many doubtful species and many that are not so, have been assigned by him. He has distinguished followers. Still, to many the proposition seems to increase rather than diminish the perplexity, for now we have two questions instead of one to contend with, viz., to separate Protista from animals on the one hand, and second, from plants on the other. Again, if I understand aright the tendency of modern research concerning this matter, the number of forms which cannot be assigned with good reason to either the vegetable or the animal series is constantly growing smaller. In short, it seems to me Protista is gradually tapering to a point as knowledge advances, and at no very distant period there will be no use for it in the sense it was first proposed and imited.

I prefer to keep to the old lines and regard these lowest beings as either plants or animals, according to the best light we have. That mistakes will be made for subsequent study to correct must be expected; but that there will be more than by any arrangement yet proposed, I can not believe.

This little swimmer from the infusion of hay is known in the system as *Heteromita*. Why is *Heteromita* an animal?

1. It feeds on organic matter of the infusion in which it flourishes. Since it contains in its body none of that peculiar substance, chlorophyl, which enables protoplasm to create its own food out of the simple substances H_2O, CO_2, and NH_3, in the presence of sun-light. On the other hand it must borrow its substance and energy from other and independent sources.

At this point two questions naturally arise which are in the nature of exceptions. (1). There are well-known and undisputed plants with the habit of animals, i. e., they feed on organic food prepared outside themselves. While it is the rule that animals feed as our infusorian does upon substance prepared ultimately by plants, and that the plant prepares its own, the Fungi and certain colorless flowering plants reverse the rule and are exceptions. That they have acquired this animal habit will not be difficult to believe if we take into account the prevalence of parasitism and the wonderful changes and modifications of form and habits which it implies. The Fungi are plants, as their life-histories, development, and structure attest. Besides they may feed on such chemicals as acetates, tartrates, and ammonia; this animals cannot do. (2). The second exception is this: certain undoubted animals, e. g., the green Hydra, some fresh-water Sponges, and Infusoria are pervaded by chlorophyl-bearing bodies. These are said to possess the power, therefore, of creating their own food in manner similar to the ordinary plant. It should be noted that if it proves to be true that these green animals have acquired the characteristic habit

of the vegetable, another fact is added tending to prove that protoplasm of either kingdom is capable of great accommodation or change of habits.

In regard to the question of the possibility of carrying one's vegetable garden in one's stomach I wish to express a doubt. I can not see that the species whose tissues are filled with these bodies, and on which, or on their products, it is supposed to feed, possesses an adequate advantage over those not thus supplied. Our green Hydra is not so abundant as the brown one, nor will it hold out longer under unfavorable conditions; it feeds as voraciously. Two masses of fresh-water sponge are often seen growing side by side, one brilliant green, the other colorless, or one mass may be partly green and partly colorless. I am unable to see that the green example or the green part has any advantage over its colorless associate. A particular infusorian, *Holophrya, sp.*, occurs in abundance in a certain sluggish stream near Buffalo. It is a deep green and often imparts its hue to the water and submerged objects on which it accumulates. A number of these were recently taken and subjected to a series of varying conditions, while check experiments were conducted with the uncolored *Enchyleodon farctus*. Under varied conditions as to light, temperature, air, and absence of food, so far as I could determine the green species possessed no advantage as to enduring qualities over the other. The usefulness of these chlorophyl bodies, if they are useful, is not, it seems to me, in the direction of nutrition or respiration.

2. The second reason why *Heteromita lens* is an animal, is the course of its life history. This is now reasonably well known and is in accord with those of others that are unmistakably of the animal series.

3. Its contractile vesicle is an attribute peculiar to the microscopic animal. True, a similar endowment has been attributed to species of Protophyta. I am not convinced

that such exist, at least, of the nature and action of those of creatures similar to *Heteromita*.

4. When the motions and behavior of these mites are taken into account one receives an impression that they are guided by intelligence and a conscious state wholly different from the influences controlling the motions of the one-celled plants; while this is not a high order of proof it should not, I think, be wholly disregarded. It certainly is in constant and instinctive use by those who study these forms.

Heteromita is clearly an animal. How stands the matter with the lowest plasmodic beings? The amœba, e. g., has no definite form, its exterior bounding parts are less differentiated than those of the animal described above. It has no specialized organs of locomotion like this one, while it has a nucleus and contracting or pulsating vacuole; it feeds also on organic particles which it takes in the solid state indifferently at any part of its body; and it moves about with a freedom and conscious direction that stamp it as one of the animal series. The very small amœba found in our creeks and ponds could not well be less complex and still exhibit the functions of animal life. Dr. Carpenter's often quoted words characterizing the Rhizopoda aptly describe it: "A little particle of apparently homogeneous jelly changing itself into a greater variety of forms than the fabled Proteus, laying hold of its food without members, swallowing it without a mouth, digesting it without a stomach — moving from place to place without muscles, and feeling without nerves." But there are lower animals it is said, the *Monera* for example. "An organism without organs which . . . consists of a freely movable, naked body composed of a structureless and homogeneous sarcode. Never differentiating nuclei within the homogeneous protoplasm." Is this existence plant or animal? For one, I am willing to leave it in "No man's land." A large number of the simplest forms once regarded as non-nucleated and without differentiation are on further study

found to be nucleated and otherwise not so simple as at first supposed. *Monera*, it seems, is already limited and may vanish entirely under the searching scrutiny of recent methods.

So far as the Moner is concerned I have to say I cannot find it. I have ransacked every likely place within my reach at all seasons without encountering such a being. I do not presume to deny its existence because I cannot find it, but I have a sufficiently wide acquaintance with unicellular plants and animals, and with their haunts, to justify me in doubting their individuality so far as my own general conclusions are concerned. I do not, however, wish to speak for others or to influence them in this matter. Both negative and positive results of my studies compel me to doubt that *Monera*, in the sense it was first described, exists as much as we all to-day doubt the existence of *Bothybius*.

As soon as beings like our *Heteromita* were discovered there arose the pertinent inquiry, Whence came they? They had no visible ancestry. A few fragments of dried grass put into a clean beaker with clear water, after a few hours brought forth living myriads. Was it therefore true that these and others like them, which people every way-side ditch and stagnant pool, came into consciousness and life from the dead by chemical and physical changes therein? It was not necessary to stand upon the belief of such an origin, and yet it was in accordance with the known facts. While mankind was ignorant of nature, fancy peopled jungle and forest with real and unreal animals spontaneously generated. This too was logical. Aristotle taught that this was one of the regular and natural modes for the production of living forms. As knowledge advanced the number of species thus accounted for faded away. After the microscope revealed a new world of minute existences, whose origin was still more difficult to verify, the belief was again strong that these were forms of life without parentage. But one after another of the coarser forms was studied and proved to follow as definite a life history as the largest animals.

Recent progress in drawing hard and fast lines about the personality of the myriad species of minute organisms leads us to wonder that so late as 1871-2 in the *Proceedings of the American Association for the Advancement of Science* and also in the *New Haven Journal of Science and Art*, same date, pp. 20 and 88, there appeared a discussion seriously purporting to trace a sequence of forms from *Protococcus* or *Chlamydococcus* to the spirally pedunculate *Vorticella*, then *Oxytrich*, and perhaps *Rotifer*.

This is truly imaginative and poetic "science." The day for such is almost, but not wholly, gone; but the "beginnings of life" have served their time, let some other branch hereafter have the honor.

Finally, within the last quarter of a century, largely by men still living, the contention over the spontaneous derivation, more especially of the simplest plants, the Bacteria, has been animated, the experimentation and analysis exact and searching. Undoubtedly, the result has been a disbelief, on the part of a great majority of naturalists, in Archebiosis. On the other hand, there are those who maintain that it is not so much a matter of experiment as a logical sequence of the doctrine of evolution.

Following the astronomer's ideas of the evolution of the earth, there was a time when the conditions were such that life could not exist; afterwards, conditions were favorable, the lowest forms originated spontaneously by the forces of nature, and, from these beginnings, all subsequent hosts, great and small, have been evolved.

The more conservative philosophers who can believe in the spontaneous generation of life only on experimental evidence are, nevertheless, logical in holding a belief in evolution of plants and animals as a fact, since the natural laws known as Darwinism apply only to already existing conscious forms. To this class the origin of life is a mystery, transcendental.

Our swarms of *Heteromita*, then, arose in the nutrient infusion from germs derived from air or water or by clinging to the hay. These germs, in turn, took their origin and potentiality from Heteromitas infinitely near this one in characters and so, backward, indefinitely from another so-called species or an original ancestral form for whose origin science is not able to account.

Admitting the distinct nature of the two parallel series of living beings, derived by the evolutionary processes from a created beginning, this interesting question arises, i. e., which was first established? As they are now found related, one sort depends wholly upon the other for the creation of those complex compounds which serve them for food — the source of substance and energy. Unless this dependence of animals is an acquired habit; as a parasite acquires habits of feeding upon the substance of its host, and at the same time loses the ability to procure its food independently, the vegetable representative must have preceded the animal. Paleontology affords no evidence affecting the question one way or the other. The earliest evidence of life in the Laurentian rocks points to the cotemporaneous existence of plants and animals. In the absence of facts men speculate. A certain chemical compound, chlorophyl, seems to be necessary to protoplasm that it may maintain and increase itself. Hence the query, was the primitive protoplasm like that of animals without chlorophyl, or like that of plants supplied with it? An eminent English scientist has suggested the possibility, at least, that animals preceded plants. The following is a statement of his views: "A conceivable state of things is that a vast amount of albuminoids and other such compounds had been brought into existence by those processes which culminated in the development of the first protoplasm, and it seems likely enough that this first protoplasm fed upon these antecedent steps in its own evolution just as animals feed on organic compounds at the present day.

"At subsequent stages in the history of this archaic living matter, chlorophyl was evolved and the power of taking carbon from carbonic acid. The green plants were rendered possible by the evolution of chlorophyl, but, through what ancestral forms they took origin or whether more than once, i. e., by more than one branch, it is difficult even to guess. The green Flagellate Protozoa (Volvocineæ) certainly furnish a connecting point by which it is possible to link on the pedigree of the green plants to the primitive protoplasm. Thus we are led to entertain the paradox that, though the animal is dependent on the plant for its food, yet, the animal preceded the plant in evolution and we look among the lower Protozoa and not among the Protophyta for the nearest representatives of that first protoplasm which was the result of a long and gradual evolution of chemical structure and the starting point of the development of organic forms."

To those who profess to believe in the production by chemical evolution of protoplasm as a specific being reproducing itself, this ingenious "paradox" is well nigh unavoidable. Chlorophyl is a product of protoplasm and could not well precede in evolution, its cause. But this, plausible as it is, depends on too many pure assumptions. It is broached only because it seems to be a logical sequence of a theory which cannot be proved, and of which many dispute even the probability. It must be assumed, first, that there was, in the remote time of primordial life, produced by chemical reactions alone, a mass of albuminoids from which protoplasm could and did spring, and on which it could subsist until an oncoming sense of hunger, as the supply of organic food, produced without antecedent life, disappeared, suggested or caused or resulted in the production of chlorophyl by which means the supply was replenished. Second, the nature and relations of the animate kingdoms, as they now exist, were once different or reversed. Neither of these propositions is sustained by a particle of chemical, biological, or paleon-

tological evidence. The past must be judged by the present. To preserve respect for the scientific method and the conclusions derived therefrom unnecessary speculation should be avoided. For one, I prefer to hold, for the present at least, the belief that in the beginning living organisms were created in their simplest forms; from these succeeding floras and faunas have been evolved.

We do not begin to know the nature of force, of matter or the origin of motion, yet, we study and investigate their laws and natural relations, and are satisfied. We rest our inquiries as to whence and what, and partly admit that these are questions past finding out by our philosophy. So, too, we may logically examine the phenomena of life, past and present, without being able or assuming to explain on scientific grounds its essence or origin. I am willing to admit the creation of protoplasm, and chlorophyl too, if necessary, by a power that is beyond nature as we understand the term.

Still I admit that the question of Archebiosis is not necessarily and forever settled; it may yet be attacked and proved experimentally by some one endowed by a peculiar genius for experimentation, one who shall be able both to see and to artificially reproduce those conditions and combinations of matter and forces, chemical and physical, which existed during the ages preceding the formation of the oldest fossil-bearing rocks.

Until such genius arises or light breaks in from some other source, I say again, I think it quite as logical and as satisfactory to keep to the old lines, at least so far as to believe that, up to a certain stage in the progress of the material world, there were no living beings, then they were created by an Almighty Power, not expressed by conditions and chemistry. I hold this simply as a naturalist, for consistency's sake, and in order to go no farther than the evidence warrants, so I am free to follow the lead of truth no matter whither it may direct.

The variety of types of the Protozoa is very great. This can scarcely be appreciated except by long and intimate study. There is neither time nor reason for an enumeration of these characters and peculiarities, although it would be interesting to trace the advance in characters as we proceeded from the highest to the lowest of the groups — we should find each type more or less intimately connected with those both above and below; that is, the line of phylogenetic descent is as clearly traceable in the protozoic as in the metazoic branches of the animal kingdom; but this is not all, for we find certain Infusoria, for example, which are evidently the types connecting the origin of the higher groups with the lower; we should also note, often with astonishment, the remarkable capability of the disassociated, specific cell, and, by the proper comparisons, find at every stage that the same functions or attributes persist in the associated units of animal tissues.

The Protozoa are separated into two grand divisions, Rhizopoda and Infusoria. The simplest of the former are naked, possibly reticulated, protoplasm only, nucleated and usually with a pulsating vacuole; they lack all specialized organs of locomotion, prehension, or digestion, while the most highly specialized Infusoria have their protoplasm surrounded by a firm, protecting, and bounding wall, well-defined and often complexly differentiated apertures for the reception of food; their bodies have definite shape and their organs of locomotion are well developed. But from the lowest to the highest may be traced such plain biogenetic relations that the development of the highest from lower is unmistakably revealed. Regard, for an example, the sedentary Tentaculifera, the most highly developed of the Infusoria; they give birth to ciliated free-swimming embryos resembling closely the adults of one of the three classes of the Ciliata which are less highly organized; this peculiar characteristic in the embryology of the Tentaculifera seems to conclusively

demonstrate their higher rank compared with the Ciliata. On the other hand, the adults are without doubt allied to the metazoic Hydrozoa which, also, have ciliated embryos attesting their ascent from the Ciliata through the Tentaculifera. So not only do the structural peculiarities and developmental phenomena of the unicellular animals plainly teach derivation by biogenetic descent throughout the branch, but also indicate the starting point of various types of the Metazoa. In substantiation of this proposition it may not be amiss to point out examples in proof. Since the succession of embryonic characters of the higher species appears to trace more or less certainly the ancestral or developmental history of that species, the connecting stages of the two branches of animals are, in many cases, already established. The larvæ of the star-fishes and sea-urchins are free-swimming little bodies, surrounded by bands of cilia which unmistakably disclose the ancestral affinities of the Echinoderms with the Peritrichous Ciliata, the class of Infusoria to which the well-known Vorticellæ or bell-animalcules belong. Another illustration may be mentioned. In the intestines of the common frog or toad may at any time be found a flat, mouthless infusorian, known as *Opalina ranarum;* it is covered throughout with fine, even cilia. There hatches from the eggs of the Cœlenterata an animal not resembling the parent, but a ciliate type, the planula so closely resembling the parasite from the frog that only an experienced observer can appreciate the difference. Indeed the great naturalist, Louis Agassiz, so late as 1852 in the *New Haven Journal of Science and Art,* declared that *Opalina* was the missing link in the history of *Distoma,* a genus of parasitic worms, and further that the embryo hatched from the egg of a planarian (another worm) was a genuine polygastric animalcule of the genus *Paramecium.* In the same paper he says, referring to the above, "with such facts before us, there is no longer any doubt respecting the character of the Polygas-

trica; they are the earliest larval condition of worms." He adds also this: "Since I have ascertained that the Vorticellæ are true Bryozoa . . . there is not a type of these microscopical beings left which hereafter can be considered a class by itself in the animal kingdom." These sentences are not quoted to call attention to an error of our revered naturalist, but to show, more thoroughly than a mere statement would do, the absolute similarity of the ciliate embryos of certain Metazoa to ciliate Infusoria.

The study of Protozoa in the light of the above and for the sake of elucidating such questions of world-wide interest can not be lightly esteemed.

The simplest Rhizopods, as stated above, consist of naked reticulated protoplasm; from this unmodified beginning may be traced ever-increasing complexity of structure. The locomotory organs may serve for an example. The uncovered forms move in two ways; by a flowing or streaming of the protoplasm as a whole, or by the protrusion of finger-like processes or threads of the body substance, called pseudopodia, which are transient or held by a permanent firm axis. Their power of extension and retraction render them organs of locomotion and prehension.

The Corticated forms have, protruding from the surface at well-defined regions, thread-like extensions of the protoplasm, called, if but few in number and relatively very long, flagella, and cilia if numerous and relatively short. These, by lashing the medium, propel the animal, or, if anchored, drive currents past the oral aperture; while in the highest divisions the cilia are replaced by styles or setæ which act very much like walking organs, and in the still more highly endowed Tentaculifera the prehensile prolongations of the body substance are tubular, usually with sucking disc at the extremity, and, often, with a spiral, coiled fibre for its retraction.

A still more highly specialized instance occurs in certain

ones of this group in which the tentacles become marvelously flexible; this is notably the case in *Ephelotidæ* and in *Podophrya flexilis*, a fresh-water species described by myself in the *Microscope* for August, 1887. In this form the long, extensible and constantly writhing arms remind one of a a veritable Octopus.

Another equally instructive series is that of the manner of and contrivances for food ingestion. In the simplest forms this takes place by simply engulfing it,— a little higher in the series it is received through the body walls at restricted areas; then a well-defined and guarded aperture is found, often reinforced by a wonderful complex system of chitinous or otherwise indurated appendages, or it may consist of sucking tubes, sometimes flexible. But enough of these details which have been enumerated not only to show the mutual relations of the groups which result from the fact of descent from common ancestors, but to present certain terms by which to make easy the explanation of the persistency of protozoic functions in the associated cells of the tissues of multicellular animals; thus the amœboid motion of the colorless blood corpucles and other cells, the contractions of the muscle cells, the cilia of the epithelium of the trachea and ventricles of the brain are examples.

The Protozoa, lowly as they are in organization, and insignificant is size, have from the dawn of animal life on the earth to the present, played a leading part in the great problems and progress of the world. Biological evidence is irresistible in proof that the first manifestation of animal life was protozoic; that the capabilities of development on this type were finally exhausted, and that there radiated from the protozoic line, at different stages, certain Metozoic types. All through the ages of change they have kept persistently to their work. The heat and drouth of summer or the frosts of winter cannot destroy them, when the water of the transient streams disappears or food fails, they simply wrap

about their frail bodies an impervious mantle to retain their own moisture, and fall asleep until returning favorable conditions restore them to activity; then again the battle of life goes fiercely on beneath the surface. Each feeds ravenously upon unicellular plants or mercilessly on those of its kind smaller than itself, and, in turn, is destined to be swallowed by one that is larger. Notwithstanding this inevitable destruction their prodigious powers of multiplication and reproduction ever maintain them against the vicissitudes of climate or the distress from enemies. This invisible link uniting the animal to the vegetable and this to the mineral, incessantly at work, is found everywhere that moisture abounds.

Saville W. Kent has gracefully said, "Inappreciable individually to the unaided vision, the countless hosts of the Infusorial world, more familiar perhaps to the popular mind under the designation animalcules, or animalcula, surround us literally on every side. They abound in the full plenitude of life alike in the running stream, the still and weed-grown pond, or the trackless ocean. Nay, more, every dew-laden blade of grass supports its multitudes, while in their semi-torpid encysted or sporalar state they permeate as dust the atmosphere we breath, and beyond question form a more or less considerable increment of the very food we swallow."

But it is not altogether the invisible and theoretical that challenge our attention and admiration, mountain masses of limestone are their enduring monuments. From the warm seas of remote geological ages to the cooler seas of the present they have been separating from sea-water the carbonate of lime and fixing the carbonic acid gas until it is manifest that they have done more than all other life towards preparing the present state of the modified crust of the earth. At the same time they have recorded in the rocky volumes by their entombed shells much of the history of the past.

This Society of Microscopists has from the first kindly

received, discussed, and published contributions to our knowledge of the various groups of the simplest plants and animals, hence it seems appropriate to briefly enumerate some of the chief problems, pertaining to the Protozoa, which are open to us for investigation, problems to the solution of which the future work of the Society should contribute. Obviously, the first work to be accomplished by American students of the group, are the identification of the species, naming, describing, and figuring the new species and genera, recording the distribution and habitats, and the presentation of the same in available publications. It is with pleasure and pride that we justly claim that in these lines the work is going forward vigorously, although the number of students is limited, and, thus far, almost exclusively restricted to fresh-water and parasitic forms. The results already recorded plainly show that the protozic fauna of our inland waters is extremely rich, presenting many characteristic and peculiar species. Many of our numerous species are undoubtedly identical or differ but slightly from European species, so slightly that I have not considered them of specific value, while many more are perfectly distinct. Dr. A. C. Stokes, who has described more of our species than anyone else, has said that the species in the sphagnous swamps of New Jersey are mostly new. The many unique forms he has brought to light appear to justify the conclusion. There remain to be explored the waters of our extensive coast and the greater part of our vast inland waters. When this has been accomplished as thoroughly as it has been done in Europe the number of species in the catalogue will be enormously increased. Then, again, there are whole groups, which have well nigh escaped observation, for example, the Proteomixa, of Lankester, a group at the very threshold of organic life, studied by leading biologists of Europe, but almost wholly neglected or overlooked in this country. A few of these species have been rediscovered, but aside from the additions by Dr. Joseph Leidy

scarcely no new data have been added to the recorded knowledge of the branch. Dr. Leidy has given us in Rhizopods of North America (1879) an admirable summary and treatise of the Rhizopoda which, with the available manuals and reports, give our students of the Rhizopoda a fair basis for work. In the field of Infusoria there is equal advantage afforded by the Manual of Kent, the magnificent treatise of Stein, the comprehensive work of Bütchli, now issuing, the papers of Entz, Maupus, and others, and the recent summary of American species, both described and identified by Dr. Stokes. So, at last, the books necessary for progress are to be had by our students; we have the microscopes surpassed by none, what then is lacking? Methods and determination that enters the mind as a directing force. Our university biological laboratories do very little in this line, the ordinary schools nothing, therefore zoölogical stations, summer biological schools, and scientific societies may justly be called upon to foster this department of research by teaching its methods.

The discovery and description of species, although necessary and naturally first in order, are not the most important or most fascinating parts of the investigation. The biological history and habits of species, their food and relations to other species are not less worthy of the student's attention. There are still many unanswered questions as regards their anatomy and physiology. Among these may be mentioned the following: The nature, behavior, and significance of the nucleus, the nervous system, the reticulation of the protoplasm, holophytic nutrition, the nature and action of the trichocysts, the passage from host to host of parasitic species and their pathological influence, the nature and function of the contractile vacuole, the production of shells, and cysts, and many more.

I cannot consent to close without alluding to the excellent work of American students of the Protozoa already to our credit. We all know Dr. J. W. Bailey as a pioneer in

American microscopy; as one who required a high degree of excellence in the microscope, and was able to obtain from it its very best performance, and who did much toward fixing a high standard for our opticians and investigators. He was an industrious student of minute types of life, and the first, I think, to publish original observations on the Protozoa in this country. His papers relating to these organisms occur in the "Smithsonian Contributions to Knowledge," beginning in 1849 and continuing to 1855. These consist of species identified, with descriptions of a few species of Rhizopoda and Infusoria. In connection with the first list is also one by Thomas Cole. Dr. Bailey remarks that "Mr. Cole is, I think, the first in this country to make a systematic study of the soft-skinned Infusoria. Both lists contain the names of species which are among our most interesting ones.

Undoubtedly, the most brilliant discovery thus far stands to the credit of Prof. H. J. Clark. He was a student, and, I think, an assistant of Professor Agassiz; hence, necessarily, a thorough investigator. Not feeling satisfied with the performance of the objectives made for Professor Agassiz by Oberhæuser, and the best to be obtained of that maker, he secured those by C. A. Spencer and R. B. Tolles. With these he was able to demonstrate structure in the Protozoa not previously suspected. I refer principally to the discovery in 1868 of the "collar" of certain flagellate monads. This was a triumph for American objectives as well as for an American naturalist. The many beautiful forms discovered in the last two decades now constitute the Order Coanoflagellata. He also discovered at this time that the tubular passages of sponges were lined with similar collared monads; hence he announced the protozoic nature of the Porifera, a proposition with which but few naturalists at present accord. This is mainly, it seems, because the supposed embryology of the sponges allies them to the Metazoa.

If these phenomena are finally interpreted differently the sponges may yet be relegated to the Protozoa. So far as the fresh water representatives are concerned, excepting the so-called embryological characters, they appear to be protozoic; especially since the discovery of *Proterospongia*, a genius of undoubted Coano-flagellate Monads which secrete a mucillaginous matrix for the shelter of the colony. Representatives of the genus are known both in Europe and America.

The Monograph of the North American Rhizopods by Dr. Leidy has been mentioned. Besides this excellent work he has published many papers on Rhizopoda, Gregarinæ, and Infusoria. Most of the infusorian species are parasitic in the intestines of insects and worms.

The foundations of the science are well laid; there are now greatly increased facilities for study so that earnest specialists are now able to advance our knowledge of these forms rapidly and with credit to our science. I will omit further mention of specific work.

I am intensely interested in the lowly creatures to which I have asked your attention, and I hope they are not wholly devoid of interest to any of you. The exactions of the occupation of an American school teacher leave comparatively little time or energy for private study or investigation. The few hours each week that I can get, I devote to the refreshing pursuit of natural science. It has come into my life as an influence as it has to many others. It seems to me, and I am led to the conclusion by observation as well as experience, that the influence of no other specialty is so edifying and enduring. The Protozoa have afforded me for the past few years the most available opportunities for that communion with nature that is both fascinating and satisfying. I can heartily recommend these beautiful objects, so wonderful in their simplicity, to any who seek a special field of natural study.

In conclusion I will quote a paragraph from Dr. Leidy, expressing beautifully the experience of every true fisherman:

"Going fishing? How often the question has been asked by acquaintances, as they have met me with rod and basket on an excursion after materials for microscopical study. Yes, has been the invariable answer, for it saved much detention and explanation. . . . No fish for the stomach, but, as the old French microscopist, Jablot, observed 'some of the most remarkable fishes that have ever been seen'; and food fishes for the intellect."